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INFORMATION TECHNOLOGIES IN MODELING OPERATION MODES OF MINING DEWATERING PLANT BASED ON ECONOMIC AND MATHEMATICAL ANALYSIS

Purpose. To ensure the energy efficiency of coal mine power systems. This can be achieved by using rational modes of a sump plant under multifactor initial conditions.

Methodology. The research technique is based on the theory of economic and mathematical analysis and the general theory of electrical engineering.

Findings. For the first time we suggested using the criterion for maximizing the mathematical expectation of the integral (total) profit (savings) $P_{\Sigma}(Y)$. The foregoing allows us to select an economically feasible diameter for the discharge pipelines of mine drainage plants. The value of the economically feasible diameter (when using this criterion) is greater than when using the criterion of minimizing the production function $P(Y)$. Therefore, it is possible to achieve maximum economic efficiency. Using reserve pipelines allows the value of the production function $P(Y)$ to be decreased and the value of the integral (total) profit $P_{\Sigma}(Y)$ to be increased. For the first time, it has been noted that when using various criteria to determine the economically advantageous diameters of the main pipelines of a mine drainage plant, the value of the economically advantageous diameter does not depend on the number of reserve pipelines used.

Originality. The research presents the theoretical substantiation of the feasibility of using economic and mathematical analysis in the search for optimal operating modes of drainage plants. We established the dependencies between the parameters of the drainage unit and the indicators of economic efficiency. This allows us to optimize the electromechanical system for energy consumption. We proposed a method for selecting the number and diameter of pressure pipelines of a mine drainage plant, taking into account a set of technological parameters that provide maximum profit.

Practical value. We selected and justified the search criteria for the optimal mode of the electromechanical mine drainage. We also developed an algorithm and software package for determining the rational diameter and number of pipelines. Mathematical dependencies make it possible to optimize the operation of a drainage plant according to two criteria, which, taking into account 20 % of the electrical consumption by a drainage system in the mine's energy balance, creates additional opportunities for increasing the energy efficiency of mining enterprises.

Keywords: *coal mine, drainage plant, pressure pipeline, economic and mathematical analysis, energy efficiency*

Introduction. Dewatering from a coalmine is one of the additional manufacturing operations which ensure the main production process – coal mining [1, 2]. The industrial operation of pumping water from the coalmine can be represented as technical and mathematical model as relation of mathematical models: numeric values and vector quantities [3]. Such a model [4] reproduces appropriately selected aspects of the physical situation, when it is possible to set compliance rules, which bind specific technical objects with certain mathematical objects and relations [5, 6]. Software part of the project was implemented using embedded programming language of the Matlab package [7, 8].

Criteria for choosing rational parameters of mine dewatering installations must be periodically reviewed and updated [5]. This is due to the following reasons:

- criteria for evaluating production efficiency are changing as economic science evolves;
- technical calculation methods, which are a part of the economic and mathematical analysis, are improving;
- the ratio of prices for equipment, materials and principles of payment for consumed electrical energy is changing.

Purpose. The purpose of this work is development of a mathematical model for defining the criterion for choosing rational parameters and operation modes of a mining dewatering plant. The time factor will be considered during transition from static to dynamic task of comparing economical effectiveness of investment and current operating costs. Further implementation of the mentioned model will be represented as a software package, based on the Matlab package. On the basis of this mathematical model, the task was to create a software package that includes a friendly graphical interface that allows using the results of this development in the form of an executable exe program.

Results. Imagine a technical-mathematical model of the production operation of pumping water from a coal mine as a

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functional Y defined on a set of functional dependencies and technical values that determine the mode of operation of a mine dewatering plant [8]

$$Y = f(n_{tp}, n_p, H_h, Q_f, \sigma_t, \rho_w, L_{constr}, q_p, d_{int}, z, H_1, A_c, B_c, a, b, c, T), \qquad (1)$$

where n_{tp} is the number of used working and reserved trunk pipelines; n_p is the number of working pumps of used type; H_h is hydraulic lift height, m; Q_f is average daily flow of water in to the mine m^3/h; σ_t is permissible temporary tensile strength of the pipe material mPa; ρ_w is the density of pumped water, kg/m^3; L_{constr} is constructing pipeline length m; q_p is the pump flow parameter, m^3/h; d_{int} is the internal diameter of the pipeline, m; z is the number of pump sections; H_1 is pressure of one section of the pump at zero flow, m; A_c, B_c, a, b, c are interpolation coefficients of pressure characteristics and pump efficiency; T is service life of fixed assets, years.

Technical regulations [9–11] are used to create a technical and mathematical model of operation mode of mining dewatering plant (1). Analysis of the technical and mathematical model allows us to get combinations of operation modes of mining dewatering plant, which provide the variability of the production function while being competitive.

The economic-mathematical equation which connects the variables, technical and economic conditions of the operation mode of the equipment of the mining dewatering plant is called the production function. We define the production function $P(Y)$ as the sum of the values of the cited capital investments $C(Y)$ in UAH, and the current operating costs $O(Y)$ (cost of production excluding depreciation), UAH/year

$$P(Y) = C(Y)E_c + O(Y), \qquad (2)$$

where E_c is the payback ratio of investments, year^{-1}.

Existence of rational parameters and operation modes of a mining dewatering plant is defined by technical and economical essences of the task. The technical essence is determined as technical and mathematical model of operation mode of mining dewatering plant (1). The economical essence of the task is represented as a certain sum of cited capital investment and current operating costs (2).

Mathematically, the analysis of the production function $P(Y)$ is reduced to finding such values of the functional Y, which send the lowest value to the production function $P(Y)$. Production function arguments are not treated as continuous variables. Most of the arguments of the production function $P(Y)$ are represented by integer (fractional) constants. Such function is continuous with respect to variables Q_f and T, and exists only if the other arguments have integer (fractional) values.

To assess the effectiveness of capital investments and the magnitude of current expenditures, economic and mathematical models which take into account the most detailed current expenditure items and investments are used. There are known economic-mathematical models of the mining dewatering plant, in which the internal diameter of the dewatering pipeline is used as the main criterion for modeling [12, 13]. The proposed economic and mathematical models adopted a number of assumptions that simplify the model, but do not have a noticeable effect on the research results. Semi-fixed operating costs such as the share of the salary of the maintenance personnel, the costs of routine maintenance and repair of pipelines, the cost of repairs and spare parts of pumping units are not taken into account.

Practically, the method of linear depreciation is usually used, where the payback ratio of investments is determined by the formula

$$E_c = \frac{1}{T}. \qquad (3)$$

This formula is used for static tasks of comparison of the technical modes variants. For a static task, it is assumed that the investment is made before the start of an operation, and the cost of production and current operating costs are constant and do not change over time. It should be noted that in conditions of actual operation of a mining dewatering plant, capital additional investments are made (the cost of capital repairs of pumping units and pipelines). Therefore, it is necessary to bring additional capital investments during the operation to the estimated point in time. From the static task of comparing variants of technological modes of operation of the mining dewatering plant follows the dynamic task of comparing operating conditions (taking into account changes in capital investments during operation). In other words, the longer the life of the mining dewatering plant is, the higher the proportion of additional capital costs is.

The payback ratio of investments in the dynamic formulation of the task of comparing options for technological modes of operation of a mining dewatering plant can be calculated by the formula

$$E_c = \frac{1}{T\left(1 + \left(\frac{1}{T}\left(1 - E_p\right)\right)^T\right)} + \frac{1}{T}, \qquad (4)$$

where E_p is probable rate of risk of capital investment ($0 \le E_p \le 1$).

The amount of capital investment $C(Y)$ depends on the cost of main pipelines and the total value of the cost of pumps and drive electric motors. Additional costs for elements of pipeline and electrical fittings and connection of pipes, mounts to executions in the barrel, installation work is taken into account according to aggregated estimates through appropriate coefficients [8, 13]. The amount of capital investment $C(Y)$ in the construction of the mining dewatering plant can be represented as

$$C(Y) = (a_p m_p n_{tp} + C_p n_p)(1 + k_{inst} + k_{add}), \qquad (5)$$

where a_p is specific cost of the pipe, UAH/kg; m_p is theoretical mass of the pipeline, kg; C_p is the cost of the pump and drive electric motor, UAH; k_{inst} is the coefficient of specific cost of installation work; k_{add} is the coefficient of specific cost of additional operations.

The main share of capital investments in the construction of a mining dewatering plant is the cost of the main and backup pipelines [11].

Theoretical mass of the main and backup pipelines m_{mp}, is determined by formula

$$m_p = 24\,661.48 \frac{0.5 H_h d_{\text{int}}}{200\sigma_t - H_h}\left(d_{\text{int}} + \frac{0.5 H_h d_{\text{int}}}{200\sigma_t - H_h}\right) L_{constr} n_{tp}. \qquad (6)$$

Let us present the product $C(Y)E_c$ in the (2) as the value of the annual depreciation charges $D(Y)$

$$D(Y) = C(Y)\left(\frac{1}{T\left(1 + \left(\frac{1}{T}\left(1 - E_p\right)\right)^T\right)} + \frac{1}{T}\right). \qquad (7)$$

The value of current operating costs (without depreciation charges), under the conditions of the single-rate tariff for consumed electricity can be determined by the formula

$$O(Y) = \frac{24 \cdot 365 \rho g H_0 Q_f n_p^3}{3.6 \cdot 10^6 \eta_{en} \eta_{dp}\left(a Q_0 n_p^2 - b Q_0^2 n_p + c Q_0^3\right)} k_{tar}, \qquad (8)$$

where $g = 9.81$ is acceleration of gravity m/s^2; η_{dp} is efficiency of mining dewatering plant electric motors; η_{en} is electric network efficiency; H_0 is modal pressure of pumping plant, m; Q_0 is modal expense of a pumping plant, m^3/h; k_{tar} is tariff rate of payment for 1 kW · h (with VAT), UAH/ kW · h.

Representation of the equality (2), as a function of integer (fractional) arguments is associated with set of real numbers, that correlate with the results of direct measurements and mathematical calculations. The specific properties of such a production function as an economic-mathematical model of the mining dewatering plant do not allow investigating it as a continuous function. However, conditional representation of the production function as a sum of interacting and continuous functions, allows using classical mathematical apparatus of extremum research. Conditions which turn $P(Y)$ to minimum are determined from the equations

$$\frac{\partial P(Y)}{\partial C(Y)}=0; \tag{9}$$

$$\frac{\partial P(Y)}{\partial O(Y)}=0. \tag{10}$$

In works [14, 15] with the economic-mathematical modeling of a mining dewatering plant, the internal diameter of the pipeline d_{int} is taken as the main criterion for evaluation (a factor attribute). An economically profitable diameter of the pipeline is such a diameter at which the value of the production function $P(Y)$ will be minimal. This statement is obviously correct, when static task of analysis of effectiveness of capital investment usage is being considered.

If we consider the diameter of the pipeline d_{int} as a continuous variable, then the existence of a single-valued minimum value of the production function $P(Y)$ will occur if the following inequalities

$$\begin{cases} \dfrac{\partial^2 P(Y)}{\partial C(Y)^2}\dfrac{\partial^2 P(Y)}{\partial O(Y)^2}-\left(\dfrac{\partial^2 P(Y)}{\partial C(Y)\partial O(Y)}\right)^2=F\left(\dfrac{a_k L}{d^{7.3}}\right)>0 \\ \dfrac{\partial^2 P(Y)}{\partial C(Y)^2}=2F>0 \\ \dfrac{\partial^2 P(Y)}{\partial O(Y)^2}=\dfrac{33.4L}{d^{7.3}}>0 \end{cases}, \tag{11}$$

where $F=f(n_{tp}, n_p, H_h, \sigma_t, \rho_p, L_p, a_p, z, q_p, Q_f, E_c)$ is the functional which defines the capital investments; $L=f_1(n_{tp}, n_p, H_h, k_{tar}, Q_0, H_0, H_1, A_k, B_k, a, b, c, \rho_w)$ is the functional, which defines current operating costs.

For any implementation of a mining dewatering plant all values from the system of inequalities (11) are positive. Therefore, an optimal and unequivocal solution is the value of the economically reasonable inner diameter of a pressure pipeline of a mining dewatering plant [1, 8].

Production operations, a feature of which is sufficient stability of economic indicators over a long period of time, are relatively small part of investment projects [8]. Methods of situational analysis, based on probabilistic estimates and subjective variation of factor signs, are used in the analysis of long-term investment projects. Considering of the grade of uncertainty of economic behavior of business entities in a market economy implies usage of probabilistic estimates as well as choice of several alternatives.

There are situations in which it is necessary to analyze organizational and management decisions: in the conditions of certainty, risk, uncertainty and conflict [8, 11]. For production operation – pumping water from the coal mine, it is advisable to consider organizational and management decisions in the conditions of certainty and risk.

During analysis of organizational and management decisions in the conditions of certainty and risk, imitation models of the object under study are used. Tightly deterministic factor economic-mathematical models are actively used [2, 8]. One of the tasks of economic and mathematical modeling using rigidly deterministic factor models is forecasting values of profit and loss. The net profit as a final indicator of the main production process depends on the value of production function $P(Y)$ in the implementation of auxiliary production operations.

Calculation results. ***Method of characteristics.*** To solve this problem in this paper the method of characteristics [8, 11] is used. The method of characteristics converts partial differential equations, for which the solution cannot be written in general terms (as, for example, the equations describing the fluid flow in a pipe) into the equations in total derivatives. The resulting nonlinear equations can then be integrated using the methods of using the equations of finite differences.

Equations of motion. Hydraulics equations that embody the principles of conservation of angular momentum and continuity in the one-line pipe, respectively, are as follows [8]

$$\begin{cases} \dfrac{P_x}{\rho}+VV_x+V-g_t\cdot\sin a+\dfrac{fV|V|}{2D}=0 \\ PP_t+P_xV+\rho\cdot a^2\cdot V_x=0\,|\times\lambda \end{cases}. \tag{12}$$

These equations can be combined with the unknown factor of l and obtain the equation [8]

$$\lambda\left[P_x\left(V+\frac{1}{\lambda\rho}\right)+P_t\right]+\left[V_x\left(V+\rho\cdot a^2\lambda\right)+V_t\right]- \\ -g\cdot\sin a+\frac{fV|V|}{2D}=0. \tag{13}$$

The arbitrary choice of two different values of l given two independent equations in the variables $P(x, t)$, $V(x, t)$, is equivalent to (12 and 13). With a suitable choice of l the simplification is possible. In particular, since P and V are functions of x and t, then if we assume that x is function t, then

$$\begin{gathered} \frac{dP(x,t)}{dt}=\frac{\partial P}{\partial x}\frac{dx}{dt}+\frac{\partial P}{\partial t}\frac{dt}{dt}=P_x\frac{dx}{dt}+Pt; \\ \frac{dV(x,t)}{dt}=\frac{\partial V}{\partial x}\frac{dx}{dt}+\frac{\partial V}{\partial t}\frac{dt}{dt}=V_x\frac{dx}{dt}+V_t. \end{gathered} \tag{14}$$

If

$$\frac{dx}{dt}=V+\frac{1}{\lambda\rho}=V+\rho a^2\lambda,, \tag{15}$$

then equation (13) becomes an ordinary differential equation

$$\lambda\frac{dP}{dt}+\frac{dV}{dt}-g\sin a+\frac{fV|V|}{2D}=0. \tag{16}$$

Solving (15), obtain

$$\begin{gathered} \lambda=\frac{1}{\rho a},\quad \frac{dx}{dt}=V+a \ -\mathit{downstream}; \\ \lambda=\frac{1}{\rho a},\quad \frac{dx}{dt}=V+a \ -\mathit{upstream}. \end{gathered} \tag{17}$$

Substituting equation (17) in (16), we obtain a system of total differential equations

$$\frac{dP}{dt}+\rho a\frac{dV}{dt}-\rho ag\sin a+\rho a\frac{fV|V|}{2D}=0; \tag{18}$$

$$\frac{dx}{dt}=V+a; \tag{19}$$

$$\frac{dP}{dt}-\rho a\frac{dV}{dt}+\rho ag\sin a-\rho a\frac{fV|V|}{2D}=0; \tag{20}$$

$$\frac{dx}{dt}=V-a. \tag{21}$$

Finite-difference scheme. For solving of the nonlinear equations (18–21) a finite difference method is used.

Implementation of the mathematical model (Fig. 1) for mining dewatering plant was performed by creating and debugging a software package using software modules as an algorithm for the functioning and interaction.

Since one of the problems was the task of creating the comprehensive software with its user-friendly graphical user interface (GUI), it was decided to carry out a set of numerical values of the original data through pop-up windows, which contains the information about the current input parameters with all the necessary explanations and tips.

Following are the results of the trial calculations for water pipe length of 3000 m, with a wall thickness of 9.525 mm steel and an inner diameter of 205 mm. Rated pump head 15 bar at nominal input pressure of 1 bar and a nominal flow rate at the outlet of the pump 1.5 m/s (at a steady flow). The mass flow rate of the working fluid was 27.8 kg/sec (at a steady flow). At the end of the pipe before the valve, a damper was installed. The flap at the end of the pipeline began to close on 5 second. Response time to complete closure flap is 1.3 seconds.

Figs. 2, 3 and 4 show the graphs of changes in the instantaneous pressure and the particle velocity of the working fluid (water in this calculation) in the nodal point section of spatio-temporal grid nearest to the throttle duct for the three variants of the dampener parameters which is installed at the end of the pipeline.

As can be seen from the graphs in Figs. 2, 3 and 4, which were obtained for the pump and piping configurations for different values of the volume of the gas cushion damping device, when sequentially building a gas cushion volume of 5, 50, 250 Lt, respectively, the oscillation frequency of the working fluid with the elastic part of the steel pipe wall varies from 0.1 Hz through 0.067 Hz and at the value of the gas cushion of 250 Lt the flow after starting the unit spike of pressure, goes to be "aligned" in close to steady flow since 25 seconds. It can be concluded that at a pressure of a gas cushion equal to 20 bar, the volume of a gas cavity damper of 250 Lt should be used to "smooth" the flow in the pipeline and almost complete suppression of the hydraulic impact phenomena spread in a liquid medium for a given parameters combination such a long pipeline.

Input of numerical values of raw data is performed through popup windows with information about the current input parameter with required explanations and tips [8, 11].

During mathematical and economic analysis of the work of the mining dewatering plant in the conditions of certainty, the straightforward task is solved to find some minimum value of the production function changing the main factor sign – the diameter of the trunk pipeline,

$$P(Y) \to \min. \qquad (22)$$

The conclusion about the rational value of the diameter of the trunk pipeline of the mine dewatering plant is made on the basis of the received results.

When choosing another criterion – maximizing the mathematical expectation of profit, possible variants of operating modes of the mining dewatering plant are researched as auxiliary production operation, using economic and mathematical model, which allows receiving the maximum of integral (total) profit $P_\Sigma(Y)$, UAH/year for the whole period of exploitation T of the mining dewatering complex.

$$P_\Sigma(Y) \to \max. \qquad (23)$$

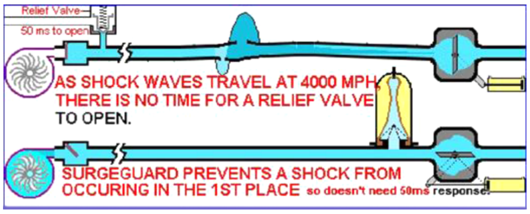

Fig. 1. GUI look at the dataset

The variant of operating mode of the mining dewatering plant which satisfies condition (13) is found by changing the main factor sign. There is a tendency of reducing the payback period of capital investments. The faster capital investments pay off, the bigger the possible amount of profit $P_\Sigma(Y)$ will be [2, 8, 11].

The amount of profit before taxes, when comparing options during the payback period is determined by the formula

$$P_i(Y) = E_c(C(Y)_{\min} - C(Y)_i) + (O(Y)_{\min} - O(Y)_i), \qquad (24)$$

where $C(Y)_{\min}$ is the amount of capital investments, when using criterion of minimization of production function, UAH; $C(Y)_i$ is the amount of possible capital costs, when using the i^{th} comparison option, UAH; $O(Y)_{\min}$ is the value of current operating costs, when using the criterion of minimization of the production function, UAH/year; $O(Y)_i$ is the value of current operating costs, when using the i^{th} comparison option, UAH/year.

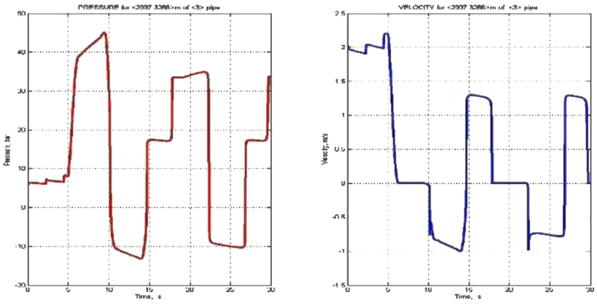

Fig. 2. Graph of instantaneous changes in pressure and particle velocity of the working fluid in the selected section of the pipeline. The pressure and volume of the dampener gas cushion are 20 bar and 5 liters, respectively

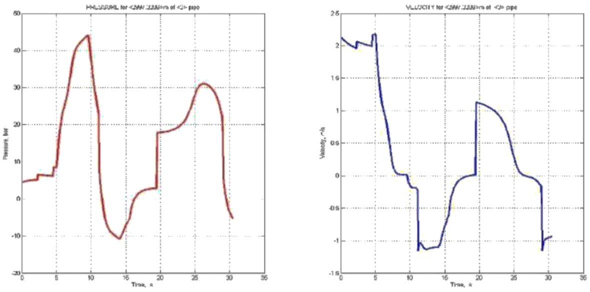

Fig. 3. Graph of instantaneous changes in pressure and particle velocity of the working fluid in the selected section of the pipeline. The pressure and volume of a gas cushion are 20 bar and 50 liters, respectively

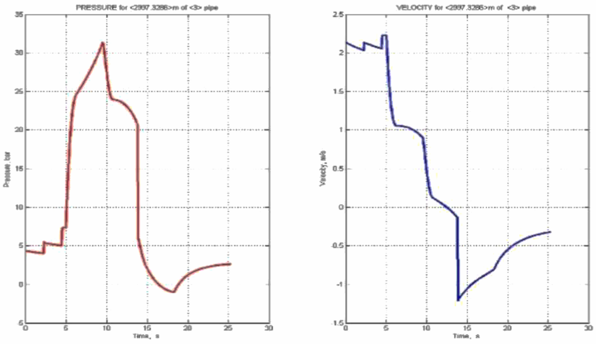

Fig. 4. Graph of instantaneous changes in pressure and particle velocity of the working fluid in the selected section of the pipeline. Pressure and volume of a gas cushion are 20 bar and 250 liters, respectively

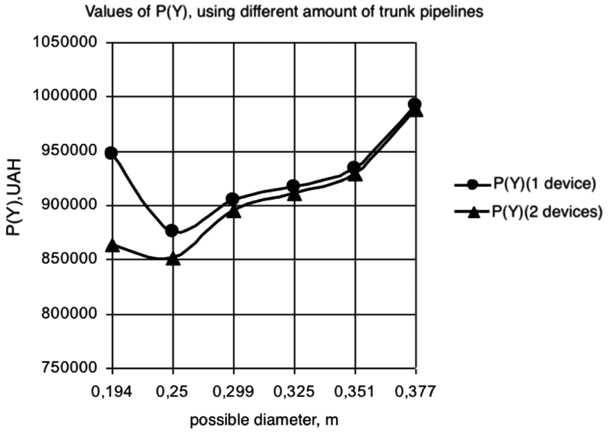

Fig. 5. Dependency of values of the production function P(Y) on possible diameters of injection pipelines when using a constant number of pumps (SCP)-300

During calculation of the amount of profit (economy) before taxes after the end of the payback period of the capital investments $P_{Pi}(Y)$, only current operating costs are considered

$$P_{Pi}(Y) = O(Y)_{\min} - O(Y)_i. \qquad (25)$$

Integral (total) profit $P(Y)$ for the whole estimated service life of the mining dewatering plant is determined by the formula

$$P_{\Sigma}(Y) = P_i(Y) + P_{Pi}(Y). \qquad (26)$$

Obviously, using the criterion of minimization of the production function $P(Y)$, economically reasonable inner diameter of injection pipeline is $d = 0.25$ m. Herewith, the value of economically reasonable diameter does not depend on the number of used backup injection pipelines. The value of the production value reduces when using backup pipes.

Fig. 6 shows dependencies of the value of profit (economy) $P_i(Y)$, $P_{Pi}(Y)$ and $P_{\Sigma}(Y)$ on possible diameters of injection pipes, when using constant count of pumps (SCP)-300 and different amount of injection pipes.

The value of the economically reasonable diameter of injection pipes for conditions of "Pavlohradska" mine is $d = 0.351$ m, when using the criterion of maximizing the mathematical expectation of profit $P_{\Sigma}(Y)$. The value of the economically reasonable diameter of injection pipes does not depend on the number of used backup injection pipelines, when using backup pipeline.

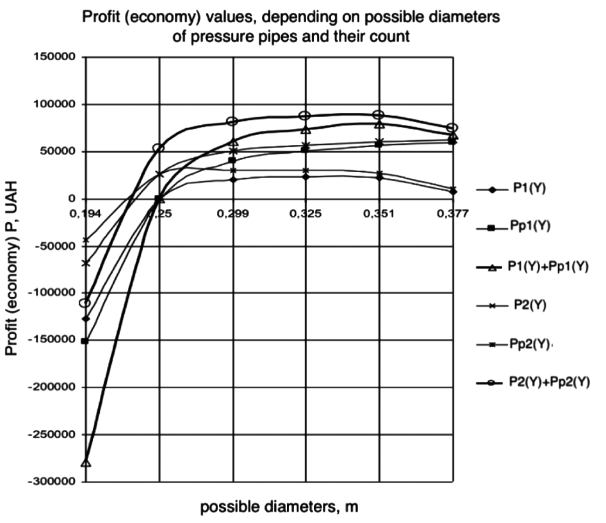

Fig. 6. Dependencies of the value of profit (economy) $P_i(Y)$, *$P_{Pi}(Y)$ and $P_{\Sigma}(Y)$ on possible diameters of injection pipes, when using a constant number of pumps (SCP)-300 and different number of injection pipes*

Conclusions. The main (consolidating) indicator in the process of comparison of the variants is enterprise profit. For the first time, it was proposed to use the criterion of maximizing the mathematical expectation of the integral (total) profit (economy) $P_{\Sigma}(Y)$ to select the economically reasonable diameter of the injection pipelines of the mining dewatering plant. The value of the economically reasonable diameter, using this criterion is bigger than using the criterion of minimization of the production function $P(Y)$. Enterprise profits (economy), however, are maximum. Usage of backup pipelines reduces the value of the production function $P(Y)$ and increases the amount of integral (total) profit. For the first time, it was noticed that using different criteria for defining economically profitable diameters of the trunk pipelines of the mining dewatering plant, the gauge of the economically profitable diameter does not depend on the number of used backup pipelines. It is advisable to use the value of the integral profit (economy) $P_{\Sigma}(Y)$ as a production function in economic and mathematical modeling operating modes of the mining dewatering plant, ensuring the main production process for the entire lifetime of the installation.

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Інформаційні технології при моделюванні режимів роботи шахтних водовідливних установок на основі економіко-математичного аналізу

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Мета. Забезпечення енергетичної ефективності систем електропостачання вугільних шахт з використанням раціональних режимів водовідливної установки при багатофакторних початкових умовах.

Методика. Методика досліджень заснована на теорії економіко-математичного аналізу й загальної теорії електротехніки.

Результати. Уперше для вибору економічно доцільного діаметра нагнітальних трубопроводів шахтних водовідливних установок запропоновано використовувати критерій максимізації математичного очікування інтегрального (сумарного) прибутку (економії) $P_{\Sigma}(Y)$. Значення економічно доцільного діаметра при використанні цього критерію більше ніж при використанні критерію мінімізації виробничої функції $P(Y)$. Економічна ефективність при цьому максимальна. Із застосуванням резервних трубопроводів знижується значення виробничої функції $P(Y)$ і зростає значення інтегрального (сумарного) прибутку $P_{\Sigma}(Y)$. Уперше відзначається, що, при використанні різних критеріїв для визначення економічно вигідних діаметрів магістральних трубопроводів шахтної водовідливної установки, величина економічно вигідного діаметра не залежить від числа застосованих резервних трубопроводів.

Наукова новизна. Дано теоретичне обґрунтування доцільності використання економіко-математичного аналізу при пошуку оптимальних режимів роботи водовідливних установок. Встановлені залежності між параметрами водовідливної установки й показниками економічної ефективності, що дозволяє оптимізувати електромеханічну систему за критерієм витрати електроенергії. Запропоновано метод вибору числа та діаметрів напірних трубопроводів шахтної водовідливної установки з урахуванням комплексу технологічних параметрів, що забезпечують максимальний прибуток.

Практична значимість. Обрані та обґрунтовані критерії пошуку оптимального режиму електромеханічної системи шахтного водовідливу. Розроблено алгоритм і програмний комплекс для визначення раціонального діаметра та кількості трубопроводів. Математичні залежності дозволяють оптимізувати роботу водовідливної установки за двома критеріями, що, з огляду на 20 % споживання електроенергії водовідливом в енергобалансі шахти, створює додаткові можливості підвищення енергетичної ефективності гірничих підприємств.

Ключові слова: *вугільна шахта, водовідливні установки, напірний трубопровід, економіко-математичний аналіз, енергоефективність*

Информационные технологии при моделировании режимов работы шахтных водоотливных установок на основе экономико-математического анализа

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Цель. Обеспечение энергетической эффективности систем электроснабжения угольных шахт с использованием рациональных режимов водоотливной установки при многофакторных начальных условиях.

Методика. Методика исследований основана на теории экономико-математического анализа и общей теории электротехники.

Результаты. Впервые для выбора экономически целесообразного диаметра нагнетательных трубопроводов шахтных водоотливных установок предложено использовать критерий максимизации математического ожидания интегральной (суммарной) прибыли (экономии) $P_{\Sigma}(Y)$. Это позволяет выбрать экономически целесообразный диаметр для выпускных отводящих трубопроводов водоотливных установок шахт. Значение экономически целесообразного диаметра при использовании этого критерия больше, чем при использовании критерия минимизации производственной функции $P(Y)$. Экономическая эффективность при этом максимальная. С применением резервных трубопроводов снижается величина значений производственной функции $P(Y)$ и возрастает величина интегральной (суммарной) прибыли $P_{\Sigma}(Y)$. Впервые отмечается, что, при использовании различных критериев для определения экономически выгодных диаметров магистральных трубопроводов шахтной водоотливной установки, величина экономически выгодного диаметра не зависит от числа применяемых резервных трубопроводов.

Научная новизна. Дано теоретическое обоснование целесообразности использования экономико-математического анализа при поиске оптимальных режимов работы водоотливных установок. Установлены зависимости между параметрами водоотливной установки и показателями экономической эффективности, что позволяет оптимизировать электромеханическую систему по расходу электроэнергии. Предложен метод выбора числа и диаметров напорных трубопроводов шахтной водоотливной установки с учетом комплекса технологических параметров, которые обеспечивают максимальную прибыль.

Практическая значимость. Выбраны и обоснованы критерии поиска оптимального режима электромеханической системы шахтного водоотлива. Разработан алгоритм и программный комплекс для определения рационального диаметра и количества трубопроводов. Математические зависимости позволяют оптимизировать работу водоотливной установки по двум критериям, что, учитывая 20 % потребления электроэнергии водоотливом в энергобалансе шахты, создает дополнительные возможности повышения энергетической эффективности горных предприятий.

Ключевые слова: *угольная шахта, водоотливная установка, напорный трубопровод, экономико-математический анализ, энергоэффективность*

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